the service in Idaho. The normal precipitation for the State for the 6 months beginning with March is 7.94 inches; during the current season the fall averaged 4.61 inches, which is but 58 per cent of the normal. The deficiency in moisture is most marked in the eastern part of the State where the fall has averaged less than 40 per cent of the normal. The table below gives for all stations in that part of Idaho included in District No. 12, and having a record covering 10 years or more, the total precipitation and departure from the normal, in inches, together with the percentage of the normal, for the 6 months from March to August, inclusive.

Station.	Precipitation, March to August, 1910, incl.	Departure from normal.	Percentage of normal.
	Inches.	*Inches.*	*Inches.*
Blackfoot	2.24	−2.83	44
Boise	3.37	−1.76	66
Cambridge	4.92	−1.79	73
Chesterfield	2.83	−4.67	38
Forney	4.90	−3.88	56
Garnet	2.13	−0.90	68
Idaho Falls	1.26	−5.75	18
Lewiston	5.53	−0.32	95
Moscow	6.33	−2.63	71
Payette	2.46	−2.01	55
Pocatello	3.41	−4.74	42
Porthill	5.72	−2.49	70

NOTES.

(Furnished by Section Director Edward L. Wells, Boise, Idaho.)

Rapid progress is being made on the work of widening and lining the main canal of the Payette–Boise Project of the U. S. Reclamation Service.

Owing to some difficulties that have arisen between the Grandview Land and Irrigation Company and the settlers under its canal, a receiver has been appointed for the company. It is announced, however, that an amicable agreement has been reached, and that money will be forthcoming to repair the dam on the Bruneau River, which has been out of commission during the present season.

Plans have been made to build the dam of the Crane Creek Irrigation Land and Power Company during the present year. When complete, the dam will create a reservoir of approximately 3,000 acres in extent, having a capacity of 70,000 acre-feet.

Work on the dam of the Idaho Irrigation Company on Wood River is progressing and it is expected that the structure will be completed during the present year.

The engineer in charge of the Salmon River Dam south of Twin Falls reports that the dam will be completed in November.

The state land board has granted the Twin Falls West End Company a delay of 5 months in the construction of its irrigation system.

The College of Agriculture of the University of Idaho, at Moscow, announces a course in farm engineering.

Some question having arisen as to the stability of the Lost River Dam, 5 miles above Mackay, Idaho, the state land board appointed a committee consisting of Daniel G. Martin, State Engineer; A. J. Wiley, of Boise, and J. H. Quinton, of Los Angeles, to make a critical inspection of the dam. The report of this committee, which was made public on September 10, states in substance that the foundation of the dam is insecure, and that to complete it according to the original specifications and fill it to its capacity would inevitably result in disaster.

Hon. Daniel G. Martin, State Engineer for Idaho, reports that, leaving out of the reckoning filings for less than 100 second-feet, there were applications for the appropriation of public waters to the number of 110 filed during the 3 months ending August 31. Of these 59 were for irrigation, 36 for power, 11 for irrigation and power combined, 2 for mining, and 2 for mining and power combined. These filings are from every county in the State, and include water from more than 50 streams.

REVIEW OF THE SPOKANE RIVER HYDROELECTRIC POWER PLANTS.

By J. C. Ralston, Mem. Am. Soc. C. E.

OROGRAPHY.

The intermountain territory of northeastern Washington, northern Idaho, and the Rocky Mountain region of western Montana, all embraced between latitude 46° to 50° N., and longitude 113° to 119° W., was by a profound system of faulting and trenching subdivided into a large complex of separate mountain ranges. These ranges have a north-south, northwest-southeast course, conformable to the basal trenches which stamped the complex into its rather rude rhombohedral subdivisions. Such ranges as the Livingston, Big Belt, Galton, Flathead, Cabinet, and Bitterroot, together with the Cœur d'Alene Mountains and others are included within the dynamic folding of this interesting territory.

The great fault zones, which subdivided these ranges, were largely the great waterways of early geologic times; but part of them, after having served through a varied history, as valleys for lava flows, retreating ice escarpments, and mighty gravel depositories, finally terminated their Pleistocene eras in the power streams of to-day. Such streams, clearly, are the Columbia, Clark Fork, or Missoula, the Kootenai, the Flathead, the Spokane, and others. Great as were their dynamic offices in the misty past, their aggregate commercial power to-day will probably exceed one million horse. The altitudes of the rivers range from 1,000 to 2,000 feet above sea level, and the mountains rise from these levels up to 8,000 and 9,000 feet. The ranges generally, particularly those south of the International Boundary, are thickly forested. The pre-Cambrian slopes are steep on all the mountain sides, including those of the Cœur d'Alenes. The latter constitutes the drainage basin of the Spokane River. Considerable of this whole complex is characterized by extensive terraces of post-Tertiary gravels, so that in the case of either the steep mountain slopes or the level terraces, the forest cover has little effect on precipitation or its run-off.

These physiographic facts coupled with the meteorologic conditions of the entire region, lying as it does between the Columbia River plateaus and the high table-lands of the Rocky Mountain foothills, places the whole area strikingly within the purview of Dr. Willis L. Moore's recent classic on precipitation as affected by forest cover.

GENERAL FEATURES OF THE SPOKANE RIVER AND ITS CATCHMENT BASIN.

The catchment basin of the Cœur d'Alene Lake, which is the head of the Spokane River, lies between latitude 46° 45′ and 47° 45′ N., and longitude 115° 30′ and 117° 0′ W. It has an area of approximately 4,000 square miles. The basin is flanked on the east by the summit of the Bitterroot Mountains, and on the west by Cœur d'Alene Lake; the former at altitudes of from 6,000 to 8,000 feet, and the latter at 2,122 feet. There are but two water courses, with their several branches, that drain the entire area. Both discharge into the lake. The whole district is mountainous, and much of it rugged. The two rivers, the St. Joseph and the Cœur d'Alene, flow through comparatively narrow valleys —from one-quarter to two miles in width. These streams on the lower stretches for about the last 30 miles have level gradients, and are virtually arms of the lake. They are regularly navigated by the largest steamboats on the lake. With the exception of narrow strips of a levee-like nature 200 to 300 feet wide, comprising the banks of each river, the valley land up to the head of navigation is a low worthless marsh. At low water both valleys are covered with marsh grass, sedge, tules, and cattails, interspersed with bunches of willow and cottonwood. At high water they are inundated. Much of the flood water remains standing on the marshes until it has been carried off by evaporation, while the main channel of the rivers within the same period drops 4 to 6 feet. The higher banks of the channels impound the flood waters and retain them from promptly draining into the rivers. Thus a measurable percentage of the flood water is lost to storage.

The mountains have generally a heavy forest growth. The precipitation varies from 24 to 36 inches, depending on altitude above sea level. Cœur d'Alene Lake has a low water area of about 42 square miles and a high water area of perhaps 50 square miles. It occupies an ancient river valley, corresponding to a zone of trenching or faulting as already outlined. Mr. F. L. Ransome, of the United States Geological Survey, in his report on the geology of the Cœur d'Alene District (Professional Paper No. 62), says this ancient valley was filled in part by Miocene basalt, was afterwards recut by the original river, leaving terraces on the old slopes, and was finally dammed on the north by deposits of Pleistocene gravels. These gravels were probably transported southward along a line of faulting in which the ancient river flowed from the retreating ice front, finally forming the lake and backing up the water of the Cœur d'Alene and St. Joseph rivers.

At the north end of the lake these foregathered waters discharge themselves into the Spokane River. Thence this river courses in a northwesterly direction to its confluence with the Columbia River. From the lake to Spokane the river has a gradient varying from 4 to 6 feet per mile, excepting at Post Falls, 9 miles below the lake, where there is a shear drop of 50 feet. This reach of the river is bordered on both sides by a beautiful, fertile valley of water-worn and glaciated gravel having a rich, but rather thin, layer of top soil which responds plenteously to irrigation. This part of the valley is underlaid by a water-bearing stratum, the gradient of which is about one-half that of the adjacent river. This is the source from which nearly all the orchards, truck gardens, and other irrigated tracts pump with electricity their water supply. The Idaho-Washington State Line is midway between Spokane and Post Falls.

At Spokane the river emerges from the western slopes of the international foothills and enters the broad lava plains of the Columbia Valley. Here it tumbles over a narrow tongue of lava, dropping 134 feet in a distance of 1,500 feet, and continues through a deep narrow valley, dropping 890 feet in the remaining 74½ miles of its length. This remarkable head is absorbed by a series of 5 principal sharply inclined rapids, at each one of which power is or can be developed under heads varying from 50 to 80 feet. Along the intervening stretches the gradients are much gentler and afford reaches in which possibly 3 substantial forebay pondages can be developed and where 2 already exist. The flow below Spokane is augmented by Latah Creek, the Little Spokane, and other minor streams which add from 5 to possibly 10 per cent to the low-water flow.

The valley from Spokane to the mouth of the river varies from one-half to 2 miles in width and is characterized by gravel terraces of varying depths up to 150 feet, while remnants of the older terraces are found still clinging to the basaltic hillsides. Near its mouth the river has cut through the Columbia River escarpment, so that the canyon walls are from 1,200 to 1,800 feet high.

RUN-OFF.

The lowest run-off known is equivalent to 0.3 second-foot per square mile of drainage area, or 1,200 second-feet for the whole Cœur d'Alene Basin, while the greatest seems to have been as much as 13 second-feet per square mile, or a total of 52,000 second-feet.

A dam was built at Post Falls on the Spokane River many years ago and used for driving a flour mill until 1905, when the site was acquired by the present owners. The works were reconstructed in 1906 upon modern lines and provided with weir, sluice, and flume openings of greater discharge capacity than existed in the old works, so that not only could a greater flood be discharged, but the extreme peaks of the floods were reduced below those prevailing prior to the new construction. With this dam in commission the lake became an ideal and very unusual impounding reservoir. Sufficient of the flood waters could be stored to raise the low water run-off from 1,200 second-feet to 2,000 second-feet—an increase of 66⅔ per cent for power purposes, plus 50 second-feet previously preempted for irrigation purposes. There is a fall in the Spokane River from the lake to the crest of the dam during high water of from 4 to 8 feet depending upon the stage of the high water. Hence it follows that no impounding due to the dam takes place, other than that which formerly existed, until the stage of the lake has dropped to the elevation of the crest of the dam, which is 2,126.6 feet in elevation. The water is held at this elevation by the regulating devices at Post Falls until the supply coming into the lake drops to the demand flow. The total pondage is then drawn upon. Fortunately the storage has so far proven sufficient to maintain the 2,000 second-feet flow until the November floods. The spring floods generally begin in April and seldom exhaust themselves until July.

EXTRANEOUS RESULTANT BENEFITS.

The building of the regulating works at Post Falls, aside from securing the desired increase of flow for the power installation at that point, results in an equal benefit to all the other plants now in operation or hereafter to be built on the lower reaches of the river. Happily, the greatest beneficiary is the city of Spokane. This city secures its water supply from a water table whose stage and supply are both dependent upon the stage and supply of the adjacent Spokane River. In addition to this the city pumps its water with hydraulic power generated by the river at the pumping works. The two-thirds increase in the flow of the river over and above the flow prior to the Post Falls improvement added a timely and very economical increase of power to the overworked pumps. Even with this augmented power the demand upon the supply has outgrown the total power capacity at the pumping plant, and the city has recently installed additional pumps which demand 2,000 horsepower from the Post Falls plant. Hence any scarcity of water or other malign condition at Post Falls involves, of necessity, not only the city's most vital welfare, but the Post Falls plant as well, also the entire tandem of plants below. Such scarcity would also reflect disastrously over the immense interstate territory served. From the combined switchboards on the river there will be vibrating this year 113,000 horsepower serving a total population of more than 250,000, scattered over a territory equal to that of the State of Massachusetts. With a field as large and diversified as this, interstate in its character, with industries and irrigation works wholly dependent upon electrical energy, any threatened or real menace at the one vulnerable vital point—the storage reservoir—would take on a profoundly serious aspect involving not alone a great fire hazard in the city of Spokane, but the industries, necessities, comforts, and rights of a commonwealth.

OUTLINE OF PLANTS.

The following is a brief outline, in physical sequence, of the 4 hydroelectric power plants on the Spokane River:

Post Falls.—The plant at Post Falls is the keystone installation of the series. It is located at a natural fall of 50 feet, where the river has divided itself into 3 channels, in each of which a precipitous fall exists and its operation constitutes the regulation of the river below. Extensive and permanent controlling works have been installed in each channel with a mid-stream type of power house constructed under the dam of the middle channel. The outline drawing succinctly illustrates the character of this plant. A concrete dam forms the up-stream wall of the power house and contains the feeder pipes, sliding head gates with their lifting devices, trash grizzlies, and screens. The power house contains five pairs of center discharge, 64½-inch Francis turbines, with horizontal shafts of 3,260 horsepower at

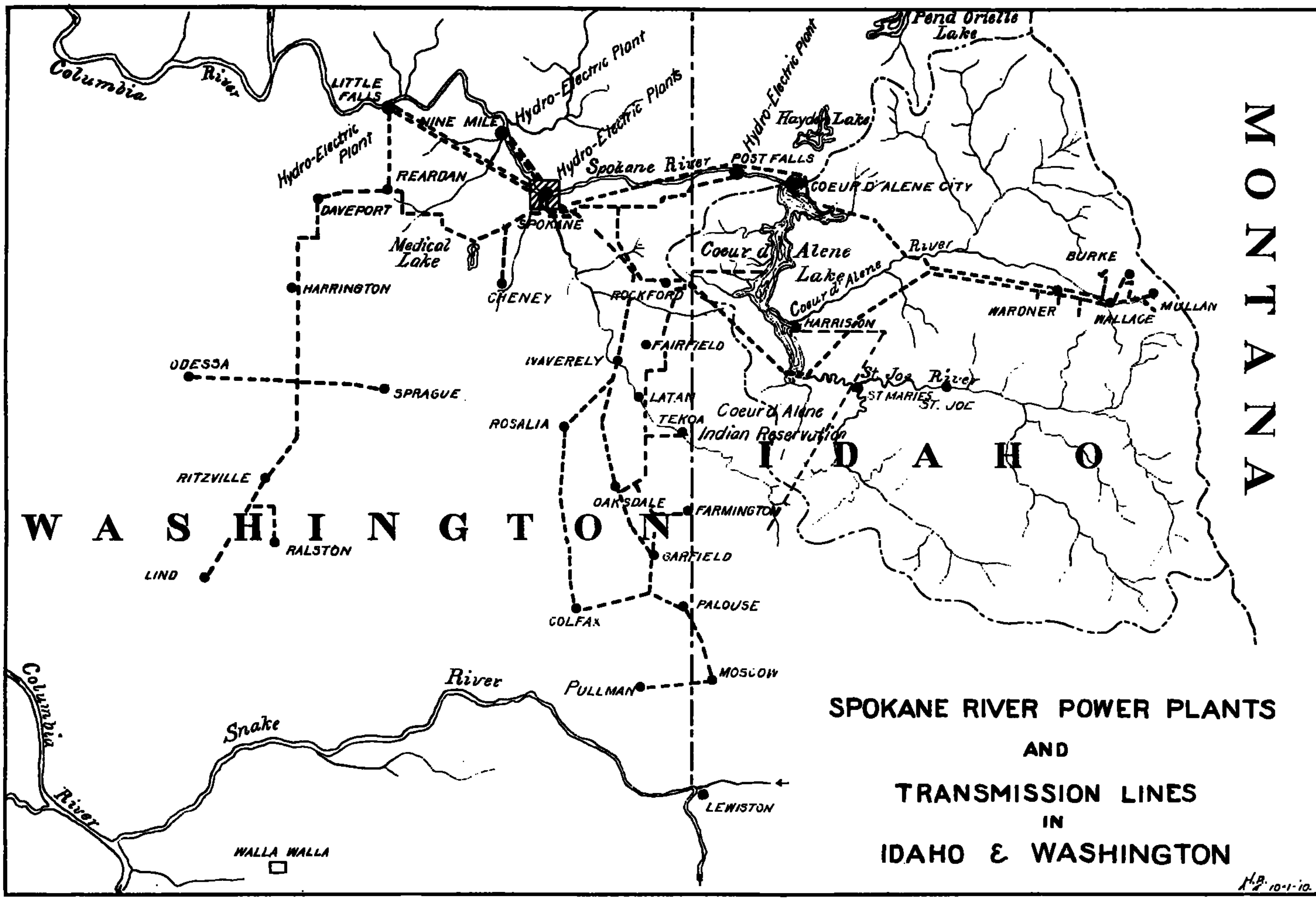

Fig. 1.

an efficiency of 80 per cent on a gate opening from 0.7 to 1.0, and an effective head of 50 feet.

Four of the wheels were built by the Platt Iron Works and one by the I. P. Morris Company. The extension of the wheel shafts carries alternating current, 2,250-kilowatt, 3-phase. 60-cycle generators, wound for 2,300 volts. They are the revolving field type and run at a speed of 138 revolutions a minute. A further extension of the shafts of four of the machines accommodates direct-connected overhung exciters. Exciters are 60 kilowatts at 125 volts, each capable of serving two alternators. The transformers are the usual oil-water type 2,300/60,000 volts, each inclosed in a brick cell with steel roller doors. Selector knife switches with transfer bus make it possible to operate directly through the individual transformer or through any other transformer of the generating units. A Tirrill regulator serves an important function in compensating the fluctuations arising from the varied load of induction motors, mine hoists, street and interurban railways.

The controlling works permit a maximum storage of 6.5 feet on Cœur d'Alene Lake, and at the same time afford a freer discharge of flood waters than existed in the old works, which had been in operation many years prior to the building of this plant.

In the south channel a concrete dam 78 feet long contains 6 gates, 6 feet wide by 13 feet high, and a spillway 42 feet long. The raising apparatus is hand operated because these gates are opened and closed but once a year. The north channel contains the principal controlling works. These consist of seven sluiceways 21 feet wide, one log sluice 12 feet wide, each rigged with combination wood and iron Taintor gates, having heavy counterweights to facilitate hand operation. In addition to these eight openings there is a main sluiceway 110 feet long controlled by a bear-trap Parker gate. This gate is operated by hydraulic force secured through tunnels in each pier, the lifting force being derived from the pressure due to the difference between the static head at the upstream inlet of the piers and the head acting directly over the gate.

The Post Falls plant is connected with the down-river plants by two separate 60,000-volt circuits. One is a direct tie, and the other has branches running to the greatest lead-producing district in the world 100 miles distant on one circuit and 65 miles on a second circuit. Also a branch to the Palouse country for the operation of flour mills and other power purposes as well as for lighting. An additional 60,000-volt line 120 miles long delivers energy to Spokane through the other plants, to the territory west of the city in the so-called "Big Bend" country.

Spokane Falls.—The pioneer plant is the one at the Spokane Falls, in the center of the city. This plant was constructed in 1892, but has received substantial additions from time to time since. Although there are 134 feet of fall available within a distance of 1,500 feet, 70 feet is the head under which this plant is operated. The water is led from a timber crib, 10 feet high, by three 10-foot and two 7-foot steel penstocks, 550 feet long, to a power house on the south bank of the river at the foot of the falls. Here are installed Francis inflow turbines, direct connected to two 2,250-kilowatt alternating current, 4,000-volt generators, one 750 direct-current, 600-volt, railway generator, one 1,200-kilowatt, 600-volt, railway generator, one 750-kilowatt, one 1,200-kilowatt, and two 200-kilowatt, direct current, 300-volt, light and power generators. This plant furnishes much of the energy used for municipal and commercial lighting, for local power, and street railway service.

A commentary worthy of note is that this plant, in conjunction with the Post Falls installation, furnishes all of the power used at the shops of the Northern Pacific and Great Northern railways. Those railways, with all their facilities for cheap transportation of coal at cost, and with their own coal mines in western Washington and central Montana, find it more economical to purchase energy than to generate it themselves by steam. In a similar economic equation the writer was commissioned about two years ago by the city of Spokane to investigate the advisability of installing a municipal lighting and power plant. After a careful inquiry into all conditions, even with a power site in hand, it was found that such a plant could not compete with the existing privately owned plants.

The pioneer Spokane plant, as heretofore suggested, uses only 70 feet of the 134 feet inherently in the falls. A new plant, however, contemplating the use of the entire falls, is in process of development. This plant when completed will no doubt retire the present lower-head plant. The new plant will be installed under a head of 148 feet. It will involve the installation of four 10,000-kilowatt, alternating current, 4,000-volt, generators, each direct connected to an 18,000-horsepower, single-runner, vertical Francis inflow type turbine. These turbines will be mounted in a vertical wheel pit, and discharge into a tail-race tunnel having a sectional area of 507 square feet, and a length of approximately 2,000 feet. This tunnel will undercut the entire falls, while the collar of the pit will receive the water from a forebay intake at the head of the falls. This plant will feed into the present distribution system of the city with its proposed extensions.

Nine-Mile plant.—This plant is located on the Spokane River about 12 miles below the city. Its type is substantially the same as the mid-stream plant shown in cross section as constructed at Post Falls, except that the power house stands at the west shore end, but under the dam. It is owned by the Inland Empire Railway. This railway operates an extension system of traction lines in the city of Spokane, also a passenger and freight line from Spokane to Cœur d'Alene City and Hayden Lake, Idaho, together with a similar, but a 25-cycle single-phase, line into the Palouse country. Both these lines serve as heavy freight feeders to Spokane. The single-phase feature which applies to the Palouse division only has perhaps been the first successful application to a heavy line in the United States, and has attracted a great deal of technical attention.

The Nine-Mile plant operates under a head of 60 feet and draws its energy from an impounding forebay embracing about 5 miles of the Spokane River. It has installed four 3,750-kilowatt, R. F. type Westinghouse, 2,200-volt generators. These generators are direct connected to horizontal Holyoke turbines. They discharge through the usual step-up apparatus, feeding two 60,000-volt circuits, transmitting to the Spokane frequency

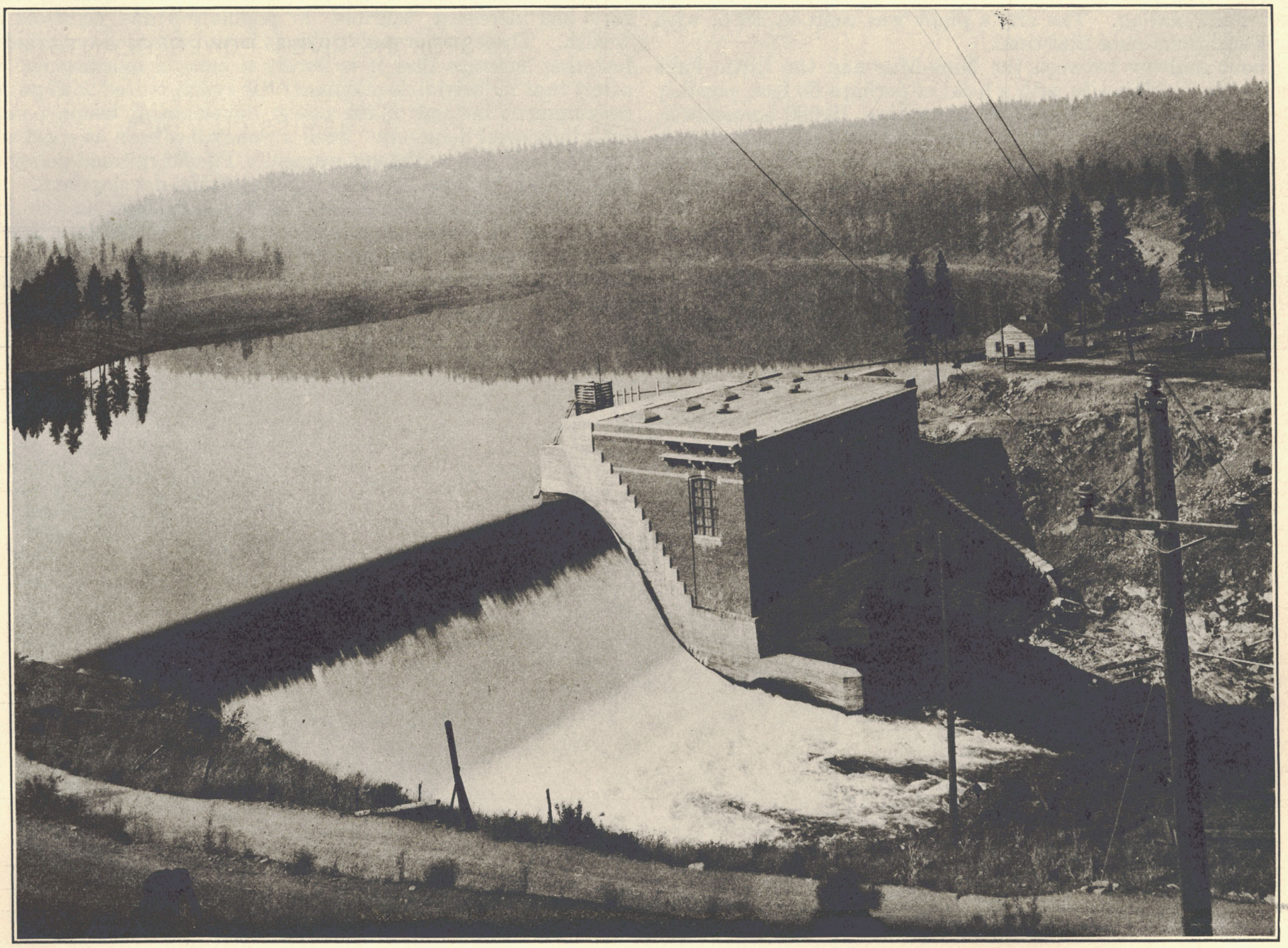

Fig. 2.—General view of the Nine-Mile hydroelectric plant, 12 miles below Spokane.

changers, and thence as 25-cycle energy at 45,000 volts to the line substations for final reduction on the single-phase line. This plant was built under contract by Messrs. Sanderson & Porter in 1908. In addition to its railway and lighting loads it supplies 2,600 horsepower to irrigation pumps in Idaho.

Little Falls plant.—This plant is located about 45 miles below Spokane on the Spokane River, and is of the same type as the Keystone plant at Post Falls. The water will be fed under a 68-foot head through four 16-foot steel flumes about 60 feet long. There are now being installed four 5,000-kilowatt, 4,000-volt alternating current generators, direct connected to four 9,000-horsepower, horizontal, inflow type, twin Francis turbines. This plant will have one double circuit, steel-tower line serving as a main tie to Spokane, and a single circuit cedar pole line feeding into the "Big Bend" country west of Spokane as well as into the city.

OTHER SITES.

There is a possible site for about 2,000 to 3,000 horsepower at a point about 7 miles above Spokane; but this site will involve such heavy cost for dam construction it is alleged that its economic feasibility may require special conditions to justify its construction.

At the up-river pumping station, 4 miles above town, the city of Spokane has developed an hydraulic plant of 3,000 horsepower capacity under a head of 19 feet, for the pumping of a part of its domestic water supply; and 2,000 horsepower additional has just been installed, the energy for which is furnished by the Post Falls station. The city's plant was built in 1896, with some additions since that time.

About midway between the Nine-Mile and the Little Falls plants is a possible site with a head of perhaps 60 feet, possibly 70 feet, capable no doubt of generating 10,000 horsepower, though this, together with the two sites yet to be mentioned, does not possess the economical features for construction enjoyed by the present plants, such sites necessarily lagging for the time when there will be a more imperative demand.

Between the Little Falls plant and the mouth of the Spokane River there are still two additional sites, one with a probable head of 75 feet and one with a head of about 85 feet, capable of delivering 10,000 and 11,000 horsepower, respectively.

TOTALITY OF POWER.

From the preceding resume it will be seen that along the entire length of the river, a distance of 108½ miles, with a low-water flow of 2,000 second-feet there can probably be developed within possible commercial limits a total of from 147,000 to 150,000 delivered horsepower, exclusive of an 18,000-horsepower steam auxiliary now built in Spokane. Of this amount there is now installed or in process of installation a total of 113,000 horsepower. The total theoretic head in the river is 1,140 feet, and of this total it is possible to utilize probably 80 per cent.

POTENCY OF INFLUENCE.

The rivers enumerated in the original subheading of this short review have many characteristics in common with the Spokane River. Where the other streans lack the amount of fall they make up in quantity of flow, and so in many respects both the rivers and the valleys are comparable in physical and other features; but in none of the valleys has there been even a rude approximation to the industrial, commercial, and agricultural development that has marked the Spokane Valley and its tributary fields. Next to the building of the railroads into the Spokane country, the most potent influence on the commercial and interstate development of the region has been these power projects. It is not a venturesome assertion to state that in no territory in the West has regional development and power development gone forward with such intimate correlation and rapidity. In the past 15 years the city of Spokane and its adjoining territory has increased fourfold in population and eightfold in wealth. These power undertakings have been such remarkable fostering agencies that it is hardly a fanciful anachronism to assert that industrial development has synchronized with power development instead of the power development keeping pace with industrial demands. Such a policy has been as constructive to the region as the government's Pacific railroad policy of 30 years ago was constructive to the national development.

These power projects have mightily quickened urban and interurban interchange and traffic; accelerated garden, orchard, dairy, and general farming, and given a powerful stimulus to industrial exploitation, not only in Washington, but in Idaho also.